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Abstract. Space weather is a new subject which has not yet become widely understood or appreciated. The University offers the unique opportunity to develop knowledge and understanding about space weather that can then be applied as graduates enter the mainstream society.

In this paper, an example of curriculum development at the İstanbul Technical University, Faculty of Aeronautics and Astronautics, for formal education related to the space environment is presented in outline.

1 Emerging space weather markets

1.1 Introduction

Since 1980 a paradigm emerged in the geosciences, called "Earth System Science" or "Earth System (ES)". There is no process or phenomenon within the ES that occurs in complete isolation from other elements of the system. While this interconnectedness is elegant and satisfying philosophically it presents an enormous challenge to researchers attempting to quantify various elements, states and processes within the system (Donald et al., 2000). Donald et al. (2000) introduce the concept of a pyramidal structure which illustrates the relation of ES and global change education in the larger interests of society. Broadly based and orderly higher-level responses address the goals and constraints of global sustainability. The future of our planet and destiny of humankind are dependent upon the interdisciplinary pyramid of ES as illustrated by Donald et al. (2000) in their paper.

At present, except for a few cases, the products of space weather research and development activities do not find customers readily. One of the reasons for this situation is the lack of awareness of the effects of space weather on terrestrial or Earth-bound systems, or on ES in general. However, for the optimization of service operations from the viewpoint of technical performance, and for the reliable continuity of services without causing health hazards and environmental electromagnetic pollution, space weather effects must be understood and appreciated. Therefore, in present day society there is a vital need for setting up education and outreach activities in the space weather field in order to create a healthy environment for the proper development of space weather markets. The space weather community must provide value-added services for the end user; that has to be the driving motivation. Last, but not the least, sufficient financial support for the space weather service providers is required in the form of competent teaching (scientific and technical personnel) and, hence, for university education in the subject.

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1.2 Some examples of services affected by space weather phenomena

1.2.1 Telecommunications

Radio communications and navigation: ionospheric perturbations caused by space weather events adversely affect Space to Space, Earth to Space and Earth to Earth telecommunications, including 3–30 MHz HF and over the horizon HF radar systems, and various satellite navigation systems.

Disasters like earthquakes, floods, etc., may be managed satisfactorily if reliable communication channels are provided. It has been experienced in various disasters, including the Turkish 1999 earthquake that GSM channels are not effective especially during the first hours of the disaster, either due to the destruction of base stations or due to the extremely heavy demand which locks up the services. In particular, and especially in such cases, HF communication is a reliable service. However, it is known that HF which uses the Earth's ionosphere as a reflector is susceptible to space weather phenomena (e.g., Tulunay et al., 2001).

Significant effort has been spent and, consequently, some software products have been developed in the communications sector for communication channel characterization and proper channel selection, especially for HF systems. Space weather data are significant inputs in such developments.

Satellite dependent communication is also susceptible to space weather.

1.2.2 Corrosion of pipelines

Cathodic protection currents must be adaptively adjusted according to the space weather conditions so that geomagnetically induced currents (GIC) do not cause excessive corrosion. Even though high strength polymers are under consideration for pipelines, existing metal pipelines will certainly be in operation for a considerable time until their economic life comes to an end.

1.2.3 Electric power line disruption

GIC's flowing through electric power lines and transformer ground paths may cause severe excess loading, resulting in even a complete breakdown of electric power services. For example, a transformer fire, such as the event that took place in Quebec during March 1989 caused an estimated economic loss between USD$ of 3–6 billion (Space Weather CD-Rom; Jansen, 2003).

1.2.4 Global Systems for Mobile (GSM) services

The quality of GSM mobile telephone services are adversely affected by space weather conditions.

1.2.5 Global Positioning System (GPS) and GPS based services

GPS systems are also susceptible to space weather. Among other effects it gives rise to ionospheric scintillations which in turn cause significant errors in navigation and positioning on the Earth. Such errors no doubt cause vital adverse effects in rescue operations (e.g., Goodwin, 1988).

GPS based services, such as automatic toll calculation, based on vehicle tracking, transport systems for goods, and military systems may suffer severely due to a decrease in positional accuracy caused by space weather events.

1.2.6 Surveys based on magnetic measurements

Various geological and other types of surveys based on accurate geomagnetic field measurements are perturbed because of the space weather condition existing at the time of the measurements.

1.2.7 Climatic and meteorological effects

Space weather affects the atmospheric circulation, precipitation and ozone depletion.

1.2.8 Hazards for aircraft crew and passengers

There are health risks from radiation exposure, especially during long distance, high altitude flights (Murtagh and Combs, 2004).

1.2.9 Risk for astronauts

Radiation in space is one of the main concerns for astronauts. The activities of astronauts, such as space walks, are planned by considering the space weather forecasts.

1.2.10 Satellite design

Space weather related anomalies must be taken into account during both the conceptual and practical design phases of satellites and their instruments. For monitoring and scenarios to avoid maximum exposure, references can be found, for example in Tulunay et al. (2001). Further information may be found for example in Donald et al. (2000). In addition to the active satellites 30 billion US$ worth satellites have been planned between the years 1997–2005 (Space Weather CD-Rom; Jansen, 2003).

2 A case study: İTÜ faculty of aeronautics and astronautics

2.1 Introduction

The Aeronautical and Astronautical Engineering Departments are parts of the Faculty of Aeronautics and Astronautics (F of AA) at the Istanbul Technical University (İTÜ). The Aeronautical Engineering Department was founded in the 1941, and has so far produced more than 2000 graduates. The Aeronautical Engineering Program currently enrolls 329 undergraduate BS students, and has 18 members of staff. The program is closely connected with that of the Astronautical Engineering Department which has 22 faculty members and 181 students in its BS program. The Meteorological Engineering Department is the third unit of the F of AA. It was founded in 1954, and more than 1000 BS students have graduated since then. There are 149 undergraduate BS students enrolled, with 21 members of staff.

Since 1998, reforms have been made in the infrastructural, academic, educational and administrative areas at the F of AA. In the field of aerospace, the Faculty of Aeronautics and Astronautics offers two separate but interrelated undergraduate programs, namely the Aeronautical Engineering and the Astronautical Engineering programs. However, with the unified engineering concept in mind, continuous improvements in the programs of these two departments have been made, in close collaboration between the staff of the departments. The faculty members of both departments not only conduct joint research activities but also discuss, decide and carry out together the currently separate undergraduate programs, as well as a common aerospace graduate program. Continuously improving the coordination between the departments allows a more effective usage of all kinds of resources.

The Academic and Executive Boards of the F of AA adapted the Continuous Improvement Project (ABET) as a means of Total Quality and Configuration Management in 1998. In 2003, a similar project was started at the end of June 2004 F of AA became a member of the certified European Union Academic (EUA) system (e.g. ITU 2002a, b, c, d, e). In this context, accreditation is the public recognition that an educational institution or program has met certain standards or criteria.

ABET was established in 1932 as the Engineers Council for Professional Development (ECPD) to unite the engineering and technical professions through professional societies in order to assess quality. As cited by the ABET Organization, the ABET Program Criteria for the Aeronautical engineering programs must demonstrate that graduates have a knowledge of aerodynamics, aerospace materials, structures, propulsion, flight mechanics, and stability and control. The Astronautical engineering programs must demonstrate that graduates have a knowledge of orbital mechanics, the space environment, attitude determination and control, telecommunications, space structures, and rocket propulsion. The programs must also demonstrate that graduates have design competence, which includes the integration of aeronautical or astronautical topics. The program faculty must have responsibility and sufficient authority to define, revise, implement, and achieve the program objectives. The program must demonstrate that the faculty members teaching upper division courses have an understanding of current professional practice in the aerospace industry.

In accordance with the criteria for accrediting engineering programs which were effective for evaluations during the 2002–2003 accreditation cycle, it is the responsibility of the institution seeking accreditation of an engineering program to demonstrate clearly that the program meets the following criteria.

Criterion 1. Students
Criterion 2. Program Educational Objectives
Criterion 3. Program Outcomes and Assessment
Criterion 4. Professional Component
Criterion 5. Faculty
Criterion 6. Facilities
Criterion 7. Institutional Support and Financial Resources
Criterion 8. Program Criteria.

Figure 1 demonstrates the number of student admissions to the F of AA between 1997 and 2003.

In 2002, 1 817 590 Turkish high school graduates sat the university entrance examination. Only 33.8% gained a place. According to the mathematics grade the Aeronautical Engineering Program at İTÜ F of AA admitted 53 students from the top 1%; the Astronautical Engineering Program admitted 32 students from the top 3% as seen in Fig. 1.

While there are three undergraduate programs (in Aeronautical, Astronautical, and Meteorology Engineering) offered at the F of AA, the graduate programs are as follows:

- MS and Ph.D. in Aeronautics;
- MS and Ph.D. in Astronautics;
- MS and Ph.D. in Meteorology;
- MBA (Master of Business Administration) in Aerospace;

State Planning Organization Supported, Advanced Technologies in Aeronautical-Astronautical Engineering (MS and Ph.D.);

Special Topics in Aerospace Engineering for Air Force Personnel (MS and Ph.D.).

The research fields of interest cover:

- Experimental Aerodynamics
- Computational Aerodynamics
- Design – Structures – Materials
- Control – Electronics - Communications
- Near Earth Space Science

Industrial and Research Projects include:

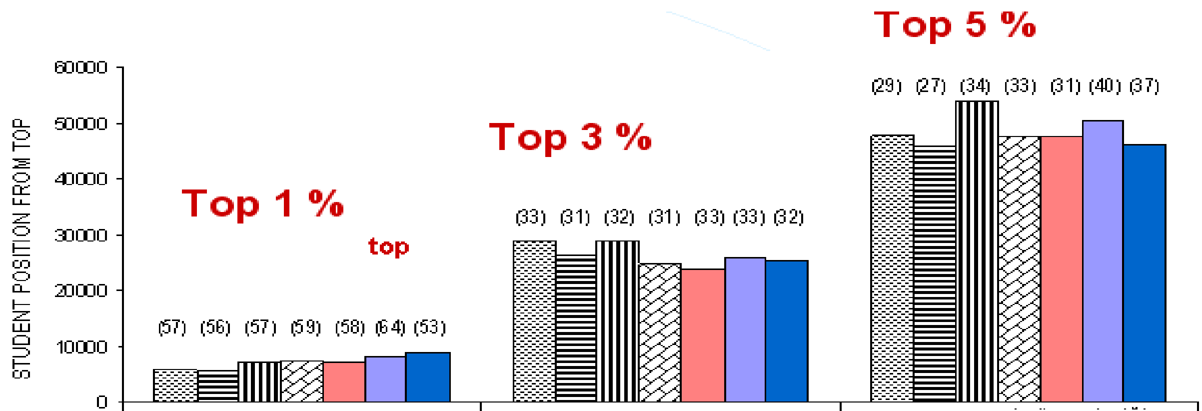
- European Union Activities (COST Actions; ESF Networks; EUROCORE: E-STAR);

NATO Projects;

- State Planning Organization Projects on Aeronautical Research and Development and Application of Advanced Technologies in Aerospace;
- Scientific and Technical Research Council (TUBITAK) of Turkey Projects;
- Undersecretariat for Defence Industries Projects (SSM);
- Technopark Projects;
- Ministry of Defence Research and Development Department (MSB ARGE) Projects;
- First and Second Air Supply and Maintenance Center Projects;

During the 2002–2003 Academic Year, 11 projects ($\sim$165 K US$) were completed, and 14 projects ($\sim$60 M US$) are currently ongoing.

The seven protocols between national and international institutes signed since 1998 have supported the interactions needed to survive. Data bases have been established for the alumni and for other administrative academic information and data.



	AERONAUTICAL	ASTRONAUTICAL	METEOROLOGICAL
1997	5799	28878	47706
1998	5672	26330	45987
1999	7118	28900	53776
2000	7486	24870	47544
2001	7154	23613	47344
2002	8134	25935	50493
2003	8967	25385	46229

Fig. 1. Student admissions in the F of AA between 1997 and 2003*.
* The Department of Aeronautical Engineering admits the top 1% of the applicants based on their ranking in Mathematics. Similar percentage numbers are indicated for the Departments of Astronautical and Meteorological Engineering. The number of students admitted to each of the programs in the designated years is given in parentheses.

3 Conclusions

As a case study, formal education on the space environment at the Faculty of Aeronautics and Astronautics of the İstanbul Technical University has been introduced and put in perspective. Figure 2 illustrates a block diagram of a control loop to illustrate our approach for the ongoing continuous improvement process. Continuous improvement in the qualifications, configuration, and quantity must become a culture, a way of life; only time will tell whether this will be the case.

The program strengths can be summarized as:

– The faculty is well qualified, enthusiastic and dedicated to the programs;

– The students are very well qualified and enthusiastically committed to the success of their program. Students are among the best qualified in the İTÜ entering class;

– The new building (completed in 2002) provides an excellent facility for teaching and research; the modern classroom, office and student-project facilities in the new building have already had a positive effect on the program in many ways, including faculty interactions and student enthusiasm for the program;

– The new ∼30 M US$ initiative of the State Planning Office projects is very likely to have positive direct, and indirect, impacts on the undergraduate program, even though this is primarily a research initiative. New instrumentation and shop facilities are already accessible to undergraduate projects;

– There is a process in place to evaluate the achievement of the educational objectives and outcomes, and for using the results of the evaluation to improve the program.

Nothing can be perfect; therefore, we can not complete the case study without mentioning some of the concerns about the evaluation. At the end of the initial process the following items have been listed as concerns:

– The program objectives should cover the longer term goals

– Students need more practical training;

– The faculty is heavily weighted toward aeronautics and would benefit from additional faculty expertise in Near-Earth Space and Astronautics;

– The faculty members should establish closer links with industrial activities.

– “emerging space weather markets”, for example, would be a contemporary dimension for the F of AA.

– The faculty members should participate in appropriate professional society actions;

– More experts from industry should be involved in the educational program.

Stronger European interactions should be encouraged through research collaborations, student exchanges, student internships and other program initiatives with European

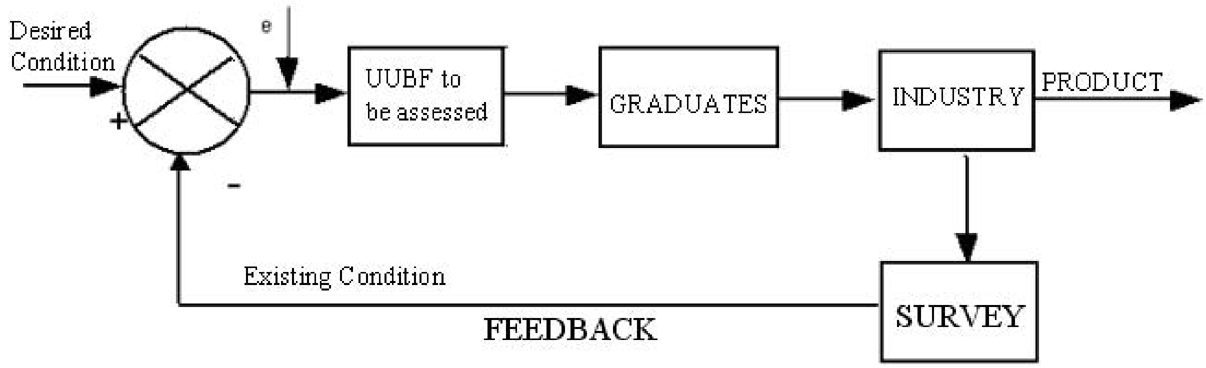


Fig. 2. Block diagram of a control loop to illustrate the Faculty of Aeronautics and Astronautics approach for the process of continuous improvement; UUBF stands for Uçak ve Uzay Bilimleri Fakültesi.

aerospace education groups (e.g., PEGASUS, AIRBUS, EADS, ESA, etc.).

"Differentiation" is important. While the old ABET criteria pushed all programs toward the average, ABET 2000 encourages institutions to set their own goals. Goals cannot, however, diverge so far from the average that a graduate fails to qualify as an engineer. Therefore, one should keep one question in mind: how far is far?

Although this paper gives only a very brief review, it may be stated that the establishment of worldwide educational institutions and Space Weather Information and Warning (SWIW) centers, working in cooperation with the already existing centers, are necessary. Such centers must be equipped with measurement and observation systems which provide local data needed not only locally but also for constructing regional and global modeling for nowcasting, forecasting and prediction. Such centers will provide data for the planning, design and operation of SWIW centers.

The SWIW centers will also create an awareness of, and also demonstrate the importance of, space weather. The centers should be an integral part of formal education and outreach activities. As a result both of the awareness of the public and the professional services, Emerging Space Weather Markets will develop satisfactorily both in quality and quantity- to create a better ecological environment and life for all on planet Earth.

Any department offering an Aerospace engineering curriculum needs to emphasize the role of space weather markets both in their own program and in the programs of neighbouring disciplines, such as electrical; communication; material; computers; mining; petroleum and gas engineering and information technologies. The same applies to the programs related to the basic sciences, business administration and management fields. Once this can be realised then the managers, administrators, decision makers themselves will be aware of the elements of space weather in actual situations and therefore, they will be equipped with knowledge and methods of seeking the right graduates to be employed at the right positions.

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